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UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1209

Washington, D. C. February, 1924

EFFECTS OF SELECTION ON THE YIELD OF A CROSS BETWEEN VARIETIES OF CORN.

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BASIS FOR THE INVESTIGATION.

The productiveness of first-generation (F_1) corn crosses and their parent varieties has been compared from time to time ever since the experiments of Beal[2] in 1876. Although the results of such comparisons have shown that many individual crosses could be used to obtain increased yields of corn, their commercial utilization has not become common. On the other hand, although a frequent method of originating new corn varieties has been to cross two strains and follow with selection, the question of the relative productiveness of the successive filial generations has received little or no experimental attention. In 1916 an opportunity was presented to study this problem in connection with an investigation of selection within self-fertilized lines and its effect on yield.

In the corn varietal experiment at Armorel, Ark., in 1915 the one outstanding strain was the F_1 generation of the cross Whatley × St. Charles White. This yielded at the rate of 81.9 bushels of air-dry shelled corn per acre, in comparison with 72.4 bushels for U. S. Selection No. 77, which ranked second. St. Charles White, the staminate parent, yielded 67 bushels per acre, or 14.9 bushels less than the cross. The pistillate parent, Whatley, was not included in this experiment because of its late maturity.

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[1] The investigations here reported were conducted cooperatively as follows: From 1915 to 1918, inclusive, with Plantation No. 1, Lee Wilson & Co., Armorel, Ark., W. B. Wallace, manager; from 1919 to 1921, inclusive, with Burdette Plantation, Burdette, Ark., J. F. Tompkins, manager; and in 1920 with W. B. Wallace, King, La. The writer wishes to express his appreciation for the facilities furnished him in connection with this work and for the many courtesies shown during its progress.

[2] Beal, W. J. Indian corn. *In* 19th Ann. Rpt. Mich. State Bd. Agr., 1879-80, p. 279-289. 1880.

St. Charles White is recommended highly by the Missouri Agricultural Experiment Station for the lowlands of southeastern Missouri, where the environment is entirely similar to that at Armorel. In addition to its significantly high yield, the cross had well-proportioned plants, was of the proper maturity, and produced a high percentage of sound grain. In view of this all-round desirability it was decided to propagate it further. Some 20 or more F_1 plants had been grown in 1915 in a garden at St. Charles, Mo., where they were isolated from other corn, and about 40 ears of F_2 seed were available from this plat. These were planted in a 2-acre field at Armorel in 1916 under the designation U. S. Selection No. 201. Open-fertilized mass selection and selection within self-fertilized lines were begun with this crop and have been continued since that time. The present bulletin reports the comparative yields of different generations under mass selection and of crosses between lines that had been self-fertilized for four generations prior to crossing.

RESULTS OF MASS SELECTION.

METHOD OF SELECTION.

The fundamental basis of selection was the production of sound grain per plant. Such factors as time of maturity, height of plant, and position and size of ear also were considered. It seemed that this would provide a standard for measuring the results of selection within self-fertilized lines and at the same time provide possibly a variety of economic value for the locality in which the experiments were being conducted.

Whatley commonly bears two or more small ears per plant. St. Charles White, the other parent, is a single-eared variety; under favorable conditions many plants will bear two ears, but three-eared stalks of St. Charles White are rare. The high yield of the F_1 generation of the cross between these varieties was due to the fact that practically every plant produced two fair-sized ears. Other data and observations also indicated that the two-eared condition was desirable. Accordingly, selection at first was largely from two-eared stalks. By 1918, however, there was too large a proportion of plants bearing three or more small ears that increased the labor of handling without apparently producing a compensating increase in yield. Beginning with this crop, therefore, more attention was paid to size and less attention to number of ears. What effect, if any, this has had on size and number of ears is shown in Table 2, which gives these data both for the different generations and for the parent varieties.

The successive crops up to and including that of 1918 were grown at Armorel, Ark. Since that time they have been grown at Burdette, Ark., about 15 miles from Armorel. From 5 to 50 bushels of seed were selected each year, and the area planted varied from 20 to 80 acres.

GROWING SEED FOR COMPARISON.

A sample of each year's seed was retained in the corn laboratory at Washington, D. C. In the absence of definite evidence, differences in the age of seed as well as differences in development due to seasonal variation must be regarded as possibly influencing productiveness. Accordingly, a plat of each generation was grown at Burdette, Ark., in 1920, and between 50 and 60 hand-pollinated ears were obtained from each plat. The pollen for these ears was taken from a different plant or plants in the same plat as the pistillate parent. In this way each generation was advanced, F_1 producing F_2, F_2 producing F_3, etc. Similarly, plats of each parent variety were grown and hand-pollinated ears representing Whatley × St. Charles White, its reciprocal cross, and each of the parent varieties were obtained. The seed of the parents planted in 1920 was obtained in 1916, the Whatley from the originator of that variety and the St. Charles White from L. H. Benne, on whose farm the original cross was made in 1914. The Whatley used in 1916 came from another source than that of 1914, but nothing has been found to suggest that this influenced the results.

The 1920 plat planted with No. 201, F_6, was on slightly lower ground and was completely drowned out following heavy rains in the spring. Consequently, no comparable F_7 seed was produced. The intention was to use the F_7 seed for planting the check plats. To take the place of this, the plants in the guard rows were hand-pollinated inter se, and the resulting seed was designated No. 201, check. The constitution of No. 201, check, is of no interest here, as its productiveness is used only to compare the different generations with the crosses between inbred strains that are considered later. All the seed used in the 1921 comparisons except No. 201, F_1, therefore, was grown in the same season and under the same conditions. No. 201, F_1, was remnant seed of the 1914 crop and therefore 6 years old when planted.

In order to avoid ambiguity, the seed classes considered and compared in these experiments are listed below, with their interrelationships indicated.

The parent varieties: Whatley and St. Charles White.

Whatley × St. Charles White (F_1) and St. Charles White × Whatley (F_1): The reciprocal crosses between the varieties mentioned, the pistillate parent being named first. These crosses were made at Burdette in 1920 by hand pollinating. Whatley × St. Charles White is the homologue of No. 201, F_1.

U. S. Selection No. 201 is used to designate the original cross, Whatley × St. Charles White, made in 1914, and the succeeding filial generations of that cross. The individual generations will be indicated in the usual way, the first as No. 201, F_1; the second as No. 201, F_2, etc.

METHOD OF COMPARISON.

The productiveness of the different classes of seed was compared at Burdette, Ark., in 1921. The soil was a better drained phase of Sharkey clay loam, with sand spots. Most of the sand blows were small, the largest not extending more than 30 feet in the longer direction. The alternation between these higher sand spots and lower areas of heavy clay was the principal cause of the irregularities in yields evidenced by the data.

The plat was marked off both ways into rows 3⅔ feet apart, and four seeds were planted in each intersection with a modified hand planter. The corn was planted on May 7. Showers on May 9 and

11 caused prompt germination, and a good stand resulted. The plat was thinned to the final stand of two plants per hill, conditions permitting, early in June. There was no rain from May 15 until July 1, just prior to blossoming, but from that time to the end of the season there was too much rather than too little moisture. The weed seeds which failed to germinate during the May-June drought when the corn was being cultivated developed rapidly following the July rains and after it was too late to control them. This not only reduced the yield as a whole but was an additional cause of irregularities in the yields. Heavy storms in late August and September broke off some of the plants, which also interfered with the results.

To represent the generations and parent strains in each case, 24 of the hand-pollinated ears grown in one of the 1920 plats were shelled and mixed thoroughly. Each composite lot so obtained was grown in a single row between one-row check plats. The rows were 10 hills long. A single comparison of all the seed classes with the necessary check plats constituted a unit which was replicated ten times. A different class, however, was used as the check in each replication or series. Whatley was the check in the first series, St. Charles White in series 2, and so on, each of the 10 seed classes in the experiment being used as the check in one series. Replications 1 to 5, inclusive, were grown end to end, and series 6 to 10 were adjacent to numbers 1 to 5. In addition to the seed grown at Burdette in 1920, the original cross, No. 201, F_1 (1914 seed), was included in each series. Because of lack of seed this strain was not used as a check. The order of planting is shown in Table 1.

This method possessed several advantages. The use of the small sections permitted 22 replications of each seed class (except No. 201, F_1), which were distributed at right angles across the experimental plat. Moreover, the odd-numbered rows constituted controls on the fertility of the different series, whereas heterogeneity within a single series was shown by the even-numbered rows. There were, therefore, alternate check plats throughout the experiment without any increase being required in the area. In addition to these advantages, each class competed with every other class, so that although competition existed there should be no distortion of its effects.

EXPERIMENTAL DATA.

Counts were made of the number of plants per row prior to harvesting. The data on suckers and barren plants are not presented, as they are practically negligible and of no significance except as they vary with a few of the extremes in productiveness of the soil. As each row was husked the ears were weighed. The product of five rows of each seed class was retained and the number of ears counted. Approximately 50 pounds of ears from this sample were shelled, the cobs weighed, and the grain determined by difference. Samples of this shelled grain were mailed to Washington in moisture-proof cans and the moisture content determined.[3]

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[3] These determinations were made in the research laboratory of Grain Investigations, Bureau of Markets and Crop Estimates, through the courtesy of Dr. D. A. Coleman, in charge.

TABLE 1.—*Yields of six successive generations of U. S. Selection No. 201 corn, its parent varieties, and later crosses between these varieties obtained at Burdette, Ark., in 1921.*

[*Explanation.*—(1) Corrections to a full-stand basis were made only for rows having 18 plants or less and for which data are given in column 5. The data for these rows in columns 6 and 7 are on this corrected-stand basis. (2) The relative yields (column 7) were computed according to the formula given in the text.]

Field row.	Seed planted.	Number of plants.	Yields per row (pounds).			
			Field weight.	Corrected-stand basis.		
				Ear corn.	Shelled grain (with 12 per cent moisture).	
					Actual.	Relative.
1	2	3	4	5	6	7
	SEC. 1 (SERIES 1 AND 6).					
No. 1	No. 201, check	20	12.0	....	9.8	....
No. 2	Whatley	20	18.0	....	14.4	15.6
No. 3	.....do	19	14.2	....	11.4	10.7
No. 4	.....do	20	15.7	....	12.6	12.6
No. 5	St. Charles White	16	12.0	15.0	12.4	11.3
No. 6	Whatley	19	19.2	....	15.4	13.7
No. 7	St. Charles White × Whatley	15	13.3	17.7	14.1	14.0
No. 8	Whatley	19	12.8	....	10.2	9.7
No. 9	No. 201, F_1 (1914 seed)	17	10.3	12.1	9.9	12.1
No. 10	Whatley	20	13.3	....	10.6	11.8
No. 11	Whatley × St. Charles White	20	13.2	....	10.6	12.7
No. 12	Whatley	20	13.3	....	10.6	12.1
No. 13	No 201, F_2	20	12.5	....	10.2	11.9
No. 14	Whatley	20	13.9	....	11.1	11.2
No. 15	No. 201, F_3	19	13.6	....	11.1	11.7
No. 16	Whatley	17	13.8	16.2	13.0	12.2
No. 17	No. 201, F_4	20	14.8	....	12.0	10.9
No. 18	Whatley	20	18.7	....	15.0	15.3
No. 19	No. 201, F_5	19	13.0	....	10.5	9.4
No. 20	Whatley	19	16.8	....	13.4	13.2
No. 21	No. 201, F_6	20	15.7	....	12.7	11.7
No. 22	Whatley	19	17.6	....	14.1	12.2
No. 23	No. 201, check	17	13.2	15.5	12.6	10.6
No. 24	Whatley	20	20.0	....	16.0	13.6
No. 25	No. 201, check	19	14.3	....	11.7	....
No. 26	No. 201, F_3	18	12.0	13.3	10.9	9.9
No. 27	Whatley	19	17.0	....	13.6	13.9
No. 28	No. 201, F_3	20	11.0	....	9.0	8.9
No. 29	St. Charles White	20	12.8	....	10.6	12.3
No. 30	No. 201, F_3	20	10.5	....	8.6	10.2
No. 31	St. Charles White × Whatley	20	11.8	....	9.4	11.4
No. 32	No. 201, F_3	20	10.0	....	8.2	10.2
No. 33	No. 201, F_1 (1914 seed)	20	11.0	....	9.0	9.9
No. 34	No. 201, F_3	20	12.7	....	10.4	9.6
No. 35	Whatley × St. Charles White	20	19.7	....	15.8	13.5
No. 36	No. 201, F_3	20	16.5	....	13.5	11.1
No. 37	.....do	18	13.0	14.4	11.8	9.5
No. 38	.....do	19	14.4	....	11.8	9.7
No. 39	No. 201, F_2	20	17.4	....	14.2	12.7
No. 40	No. 201, F_3	20	13.4	....	11.0	9.2
No. 41	No. 201, F_4	19	16.1	....	13.0	12.4
No. 42	No. 201, F_3	18	11.4	12.7	10.4	9.2
No. 43	No. 201, F_5	19	16.0	....	12.9	12.8
No. 44	No. 201, F_3	20	12.4	....	10.1	9.9
No. 45	No. 201, F_6	19	12.9	....	10.4	10.7
No. 46	No. 201, F_3	19	12.0	....	9.8	9.9
No. 47	No. 201, check	20	13.8	....	11.2	11.5
No. 48	No. 201, F_3	17	10.4	12.2	10.0	8.4
No. 49	No. 201, check	20	16.4	....	13.4	....
	SEC. 2 (SERIES 2 AND 7).					
No. 1	No. 201, check	20	13.8	....	11.2	....
No. 2	St. Charles White	20	12.6	....	10.4	10.6
No. 3	Whatley	20	14.3	....	11.4	11.5
No. 4	St. Charles White	20	14.1	....	11.6	11.9
No. 5	.....do	20	14.4	....	11.9	11.1
No. 6	.....do	19	14.8	....	12.2	10.8
No. 7	St. Charles White × Whatley	20	18.6	....	14.8	14.8
No. 8	St. Charles White	19	12.1	....	10.0	8.0
No. 9	No. 201, F_1 (1914 seed)	15	12.7	16.9	13.8	13.9
No. 10	St. Charles White	19	14.5	....	12.0	10.5

TABLE 1.—*Yields of six successive generations of U. S. Selection No. 201 corn, its parent varieties, and later crosses between these varieties obtained at Burdette, Ark., in 1921*—Continued.

Field row.	Seed planted.	Number of plants.	Yields per row (pounds).			
			Field weight.	Corrected-stand basis.		
				Ear corn.	Shelled grain (with 12 per cent moisture).	
					Actual.	Relative.
1	2	3	4	5	6	7
	SEC. 2—Continued.					
No. 11	Whatley × St. Charles White	19	15.3	....	12.3	11.6
No. 12	St. Charles White	20	14.0	....	11.6	11.2
No. 13	No. 201, F_2	19	15.0	....	12.2	11.5
No. 14	St. Charles White	20	14.4	....	11.9	11.7
No. 15	No. 201, F_3	19	11.6	....	9.5	11.0
No. 16	St. Charles White	20	8.7	....	7.2	9.8
No. 17	No. 201, F_4	20	8.0	....	6.5	9.6
No. 18	St. Charles White	20	9.4	....	7.8	11.6
No. 19	No. 201, F_5	19	11.0	....	8.9	10.7
No. 20	St. Charles White	20	13.0	....	10.7	10.5
No. 21	No. 201, F_6	18	16.0	17.8	14.4	12.7
No. 22	St. Charles White	20	17.6	....	14.5	11.1
No. 23	No. 201, check	18	15.6	17.3	14.1	10.9
No. 24	St. Charles White	18	15.4	17.1	14.1	11.3
No. 25	No. 201, check	19	14.2	....	11.6	....
No. 26	No. 201, F_4	19	17.1	....	13.8	13.3
No. 27	Whatley	20	15.2	....	12.2	11.0
No. 28	No. 201, F_4	19	14.6	....	11.8	12.6
No. 29	St. Charles White	16	9.8	12.3	10.1	10.4
No. 30	No. 201, F_4	20	13.0	....	10.5	11.6
No. 31	St. Charles White × Whatley	19	14.2	....	11.3	11.8
No. 32	No. 201, F_4	18	12.8	14.2	11.5	11.5
No. 33	No. 201, F_1 (1914 seed)	15	10.7	14.3	11.7	12.1
No. 34	No. 201, F_4	19	13.2	....	10.7	11.4
No. 35	Whatley × St. Charles White	19	12.2	....	9.8	10.1
No. 36	No. 201, F_4	16	11.6	14.5	11.7	14.8
No. 37	No. 201, F_3	17	8.5	10.0	8.2	8.0
No. 38	No. 201, F_4	20	14.7	....	11.9	14.6
No. 39	No. 201, F_2	18	10.2	11.3	9.2	9.6
No. 40	No. 201, F_4	20	12.6	....	10.2	11.2
No. 41	do	19	14.2	....	11.5	13.9
No. 42	do	19	11.0	....	8.9	9.8
No. 43	No. 201, F_5	17	9.9	11.6	9.4	12.0
No. 44	No. 201, F_4	20	11.3	....	9.1	10.1
No. 45	No. 201, F_6	20	14.0	....	11.3	12.8
No. 46	No. 201, F_4	18	12.6	14.0	11.3	12.1
No. 47	No. 201, check	19	11.2	....	9.1	8.2
No. 48	No. 201, F_4	20	17.6	....	14.2	14.1
No. 49	No. 201, check	19	14.4	....	11.7	....
	SEC. 3 (SERIES 3 AND 8).					
No. 1	No. 201, check	20	13.5	....	11.0	....
No. 2	St. Charles White × Whatley	20	17.8	....	14.2	13.7
No. 3	Whatley	19	16.1	....	12.9	11.4
No. 4	St. Charles White × Whatley	19	17.6	....	14.0	13.8
No. 5	St. Charles White	19	13.7	....	11.3	10.2
No. 6	St. Charles White × Whatley	20	17.3	....	13.8	12.9
No. 7	do	20	17.6	....	14.0	12.7
No. 8	do	20	17.2	....	13.7	11.5
No. 9	No. 201, F_1 (1914 seed)	17	14.0	16.5	13.4	12.0
No. 10	St. Charles White × Whatley	20	17.9	....	14.2	12.2
No. 11	Whatley × St. Charles White	20	16.4	....	13.2	11.7
No. 12	St. Charles White × Whatley	20	17.4	....	13.9	12.7
No. 13	No. 201, F_2	20	15.7	....	12.8	11.5
No. 14	St. Charles White × Whatley	20	17.4	....	13.9	13.0
No. 15	No. 201, F_3	16	9.9	12.4	10.1	9.9
No. 16	St. Charles White × Whatley	20	14.7	....	11.7	12.3
No. 17	No. 201, F_4	19	13.1	....	10.6	11.4
No. 18	St. Charles White × Whatley	20	14.6	....	11.6	12.4
No. 19	No. 201, F_5	20	13.4	....	10.8	13.5
No. 20	St. Charles White × Whatley	19	10.5	....	8.4	9.1
No. 21	No. 201, F_6	18	11.6	12.9	10.4	13.6
No. 22	St. Charles White × Whatley	20	13.4	....	10.7	11.7
No. 23	No. 201, check	20	11.8	....	9.6	10.6
No. 24	St. Charles White × Whatley	20	14.9	....	11.9	12.6

TABLE 1.—*Yields of six successive generations of U. S. Selection No. 201 corn, its parent varieties, and later crosses between these varieties obtained at Burdette, Ark., in 1921*—Continued.

Field row.	Seed planted.	Number of plants.	Yields per row (pounds).			
			Field weight.	Corrected-stand basis.		
				Ear corn.	Shelled grain (with 12 per cent moisture).	
					Actual.	Relative.
1	2	3	4	5	6	7
	SEC. 3—Continued.					
No. 25	No. 201, check	20	12.0	....	9.8	....
No. 26	No. 201, F_5	19	16.0	....	12.9	12.0
No. 27	Whatley	20	18.6	....	14.9	13.8
No. 28	No. 201, F_5	20	14.6	....	11.8	10.8
No. 29	St. Charles White	20	13.6	....	11.2	11.5
No. 30	No 201, F_5	20	13.0	....	10.5	10.2
No. 31	St. Charles White × Whatley	20	16.3	....	13.0	13.7
No. 32	No. 201, F_5	20	13.8	....	11.2	10.2
No. 33	No. 201, F_1 (1914 seed)	18	13.3	14.8	12.1	12.8
No. 34	No. 201, F_5	16	10.2	12.8	10.3	9.7
No. 35	Whatley × St. Charles White	20	15.2	....	12.2	13.9
No. 36	No. 201, F_5	20	12.0	....	9.7	9.3
No. 37	No. 201, F_3	18	12.8	14.2	11.6	12.7
No. 38	No. 201, F_5	20	13.9	....	11.2	10.2
No. 39	No. 201, F_2	16	11.6	14.5	11.8	11.4
No. 40	No. 201, F_5	17	13.2	15.5	12.5	12.6
No. 41	No. 201, F_4	20	13.4	....	10.8	10.1
No. 42	No. 201, F_5	20	14.7	....	11.9	13.0
No. 43	do	20	12.5	....	10.1	9.6
No. 44	do	20	15.0	....	12.1	11.7
No. 45	No. 201, F_6	20	16.8	....	13.6	12.3
No. 46	No. 201, F_5	19	16.2	....	13.1	11.7
No. 47	No. 201, check	17	11.3	13.3	10.8	10.1
No 48	No. 201, F_5	17	12.0	14.1	11.4	10.4
No. 49	No. 201, check	20	14.3	....	11.7	....
	SEC. 4 (SERIES 4 AND 9).					
No. 1	No. 201, check	20	14.3	....	11.7	....
No. 2	Whatley × St. Charles White	20	18.3	....	14.7	13.5
No. 3	Whatley	18	14.9	16.6	13.3	12.0
No. 4	Whatley × St. Charles White	20	16.3	....	13.1	13.1
No. 5	St. Charles White	19	12.7	....	10.5	9.8
No. 6	Whatley × St. Charles White	20	17.0	....	13.7	14.4
No. 7	St. Charles White × Whatley	20	14.9	....	11.9	12.2
No. 8	Whatley × St. Charles White	20	13.2	....	10.6	10.4
No. 9	No. 201, F_1 (1914 seed)	20	14.1	....	11.5	10.6
No. 10	Whatley × St. Charles White	18	18.6	20.7	16.6	15.0
No. 11	do	20	17.2	....	13.8	11.4
No. 12	do	20	17.0	....	13.7	12.1
No. 13	No. 201, F_2	20	16.1	....	13.1	11.7
No. 14	Whatley × St. Charles White	18	16.1	17.9	14.4	14.0
No. 15	No. 201, F_3	12	6.6	11.0	9.0	7.1
No. 16	Whatley × St. Charles White	11	11.8	21.4	17.2	15.7
No. 17	No. 201, F_4	14	12.8	18.3	14.8	11.6
No. 18	Whatley × St. Charles White	20	18.2	....	14.6	11.3
No. 19	No. 201, F_5	19	18.3	....	14.8	12.4
No. 20	Whatley × St. Charles White	18	17.0	18.9	15.2	15.4
No. 21	No. 201, F_6	20	9.7	....	7.8	8.0
No. 22	Whatley × St. Charles White	20	11.3	....	9.1	14.4
No. 23	No. 201, check	19	7.4	....	6.0	9.6
No. 24	Whatley × St. Charles White	18	7.4	8.2	6.6	9.7
No. 25	No. 201, check	18	8.8	9.8	8.0	....
No. 26	No. 201, F_6	20	11.7	....	9.5	11.9
No. 27	Whatley	20	13.0	....	10.4	11.8
No. 28	No. 201, F_6	20	13.3	....	10.8	11.3
No. 29	St. Charles White	20	15.0	....	12.4	14.3
No. 30	No. 201, F_6	19	11.4	....	9.2	9.2
No. 31	St. Charles White × Whatley	20	13.9	....	11.1	14.0
No. 32	No. 201, F_6	20	11.3	....	9.1	11.1
No. 33	No. 201, F_1 (1914 seed)	17	8.0	9.4	7.7	9.1
No. 34	No. 201, F_6	20	12.8	....	10.4	12.3
No. 35	Whatley × St. Charles White	20	14.6	....	11.7	12.8
No. 36	No. 201, F_6	20	13.1	....	10.6	12.3
No. 37	No. 201, F_3	19	9.6	....	7.9	8.3

TABLE 1.—*Yields of six successive generations of U. S. Selection No. 201 corn, its parent varieties, and later crosses between these varieties obtained at Burdette, Ark., in 1921*—Continued.

Field row.	Seed planted.	Number of plants.	Yields per row (pounds).			
			Field weight.	Corrected-stand basis.		
				Ear corn.	Shelled grain (with 12 per cent moisture).	
					Actual.	Relative.
1	2	3	4	5	6	7
	Sec. 4—Continued.					
No. 38	No. 201, F_6	20	14.1	....	11.4	11.9
No. 39	No. 201, F_2	20	15.6	....	12.7	11.4
No. 40	No. 201, F_6	20	17.6	....	14.2	12.4
No. 41	No. 201, F_4	20	16.4	....	13.3	11.5
No. 42	No. 201, F_6	20	15.4	....	12.5	11.2
No. 43	No. 201, F_5	20	15.2	....	12.3	10.8
No. 44	No. 201, F_6	20	16.8	....	13.6	12.4
No. 45	do	20	16.0	....	12.9	10.4
No. 46	do	20	18.5	....	15.0	12.6
No. 47	No. 201, check	18	14.4	16.0	13.0	10.6
No. 48	No. 201, F_6	20	16.3	....	13.2	10.6
No. 49	No. 201, check	20	15.6	....	12.7	....
	Sec. 5 (Series 5 and 10).					
No. 1	No. 201, check	19	14.8	....	12.1	....
No. 2	No. 201, F_2	18	13.5	15.0	12.2	11.1
No. 3	Whatley	18	14.9	16.6	13.3	13.7
No. 4	No. 201, F_2	19	11.7	....	9.5	9.8
No. 5	St. Charles White	18	10.7	11.9	9.8	11.3
No. 6	No. 201, F_2	20	12.1	....	9.9	11.5
No. 7	St. Charles White × Whatley	20	13.2	....	10.5	13.0
No. 8	No. 201, F_2	20	10.1	....	8.2	12.8
No. 9	No. 201, F_1 (1914 seed)	18	4.6	5.1	4.2	6.2
No. 10	No. 201, F_2	20	8.6	....	7.0	14.2
No. 11	Whatley × St. Charles White	20	8.8	....	7.1	9.5
No. 12	No. 201, F_2	20	11.9	....	9.7	12.4
No. 13	do	20	14.0	....	11.4	11.3
No. 14	do	20	15.9	....	13.0	12.6
No. 15	No. 201, F_3	20	13.0	....	10.6	9.3
No. 16	No. 201, F_2	16	12.2	15.3	12.5	12.7
No. 17	No. 201, F_4	20	13.4	....	10.8	10.2
No. 18	No. 201, F_2	17	11.7	13.8	11.3	12.2
No. 19	No. 201, F_5	19	13.0	....	10.5	10.3
No. 20	No. 201, F_2	19	14.2	....	11.6	13.2
No. 21	No. 201, F_6	19	11.9	....	9.6	10.3
No. 22	No. 201, F_2	19	11.3	....	9.2	9.3
No. 23	No. 201, check	12	8.8	14.7	12.0	13.1
No. 24	No. 201, F_2	17	11.7	13.8	11.3	10.0
No. 25	No. 201, check	19	13.8	....	11.2	....
No. 26	do	20	11.0	....	9.0	9.5
No. 27	Whatley	20	13.1	....	10.5	13.2
No. 28	No. 201, check	18	8.2	9.1	7.4	8.4
No. 29	St. Charles White	17	10.7	12.6	10.4	12.2
No. 30	No. 201, check	19	12.5	....	10.2	10.3
No. 31	St. Charles White × Whatley	20	16.2	....	12.9	13.0
No. 32	No. 201, check	20	12.6	....	10.3	10.0
No. 33	No. 201, F_1 (1914 seed)	18	11.8	13.1	10.7	12.1
No. 34	No. 201, check	20	9.7	....	7.9	9.1
No. 35	Whatley × St. Charles White	20	11.4	....	9.2	11.0
No. 36	No. 201, check	20	11.4	....	9.3	10.9
No. 37	No. 201, F_3	20	12.4	....	10.1	10.6
No. 38	No. 201, check	19	12.8	....	10.4	9.2
No. 39	No. 201, F_2	17	14.6	17.2	14.0	13.1
No. 40	No. 201, check	16	11.4	14.3	11.7	9.5
No. 41	No. 201, F_4	13	11.4	17.5	14.1	12.7
No. 42	No. 201, check	15	10.3	13.7	11.2	9.9
No. 43	No. 201, F_5	15	11.0	14.7	11.9	11.9
No. 44	No. 201, check	12	7.0	11.7	9.5	9.6
No. 45	No. 201, F_6	18	12.0	13.3	10.8	12.6
No. 46	No. 201, check	13	6.5	10.0	8.2	7.6
No. 47	do	16	12.4	15.5	12.6	14.0
No. 48	do	15	9.5	12.7	10.4	9.2
No. 49	do	18	12.0	13.3	10.8	....

Table 1.—*Yields of six successive generations of U. S. Selection No. 201 corn, its parent varieties, and later crosses between these varieties obtained at Burdette, Ark., in 1921*—Continued.

Summary of the Actual Yields.

Replication.	Whatley.	St. Charles White.	St. Charles White × Whatley.	No. 201, F_1 (1914 seed).	Whatley × St. Charles White.	No. 201, F_2.	No. 201, F_3.	No. 201, F_4.	No. 201, F_5.	No. 201, F_6.	No. 201, check.
Pounds per row:											
No. 1	11.4	12.4	14.1	....	10.6	10.2	11.1	12.0	10.5	12.7	12.6
No. 2	11.4	11.9	14.8	....	12.3	12.2	9.5	6.5	8.9	14.4	14.1
No. 3	12.9	11.3	14.0	....	13.2	12.8	10.1	10.6	10.8	10.4	9.6
No. 4	13.3	10.5	11.9	....	13.8	13.1	9.0	14.8	14.8	7.8	6.0
No. 5	13.3	9.8	10.5	....	7.1	11.4	10.6	10.8	10.5	9.6	12.0
No. 6	13.6	10.6	9.4	....	15.8	14.2	11.8	13.0	12.9	10.4	11.2
No. 7	12.2	10.1	11.3	....	9.8	9.2	8.2	11.5	9.4	11.3	9.1
No. 8	14.9	11.2	13.0	....	12.2	11.8	11.6	10.8	10.1	13.6	10.8
No. 9	10.4	12.4	11.1	....	11.7	12.7	7.9	13.3	12.3	12.9	13.0
No. 10	10.5	10.4	12.9	....	9.2	14.0	10.1	14.1	11.9	10.8	12.6
No. 11	14.4	10.4	14.2	....	14.7	12.2	10.9	13.8	12.9	9.5	9.0
No. 12	12.6	11.6	14.0	....	13.1	9.5	9.0	11.8	11.8	10.8	7.4
No. 13	15.4	12.2	13.8	9.9	13.7	9.9	8.6	10.5	10.5	9.2	10.2
No. 14	10.2	10.0	13.7	13.8	10.6	8.2	8.2	11.5	11.2	9.1	10.3
No. 15	10.6	12.0	14.2	13.4	16.6	7.0	10.4	10.7	10.3	10.4	7.9
No. 16	10.6	11.6	13.9	11.5	13.7	9.7	13.5	11.7	9.7	10.6	9.3
No. 17	11.1	11.9	13.9	4.2	14.4	13.0	11.8	11.9	11.2	11.4	10.4
No. 18	13.0	7.2	11.7	9.0	17.2	12.5	11.0	10.2	12.5	14.2	11.7
No. 19	15.0	7.8	11.6	11.7	14.6	11.3	10.4	8.9	11.9	12.5	11.2
No. 20	13.4	10.7	8.4	12.1	15.2	11.6	10.1	9.1	12.1	13.6	9.5
No. 21	14.1	14.5	10.7	7.7	9.1	9.2	9.8	11.3	13.1	15.0	8.2
No. 22	16.0	14.1	11.9	10.7	6.6	11.3	10.0	14.2	11.4	13.2	10.4
Average	12.7 ±.26	11.1 ±.25	12.5 ±.25	10.4 ±.61	12.5 ±.42	11.2 ±.28	10.2 ±.20	11.5 ±.28	11.4 ±.21	11.5 ±.29	10.3 ±.29
Bushels per acre:											
Average	73.48 ±1.50	64.22 ±1.45	72.32 ±1.45	60.17 ±3.53	72.32 ±2.43	64.80 ±1.62	59.01 ±1.16	66.54 ±1.62	65.96 ±1.21	66.54 ±1.68	59.59 ±1.68

Summary of the Relative Yields.

Replication.	Whatley.	St. Charles White.	St. Charles White × Whatley.	No. 201, F_1 (1914 seed).	Whatley × St. Charles White.	No. 201, F_2.	No. 201, F_3.	No. 201, F_4.	No. 201, F_5.	No. 201, F_6.	No. 201, check.
Pounds per row:											
No. 1	15.6	11.3	14.0	....	12.7	11.9	11.7	10.9	9.4	11.7	10.6
No. 2	10.7	12.3	11.4	....	13.5	12.7	9.9	12.4	12.8	10.7	11.5
No. 3	12.6	10.6	14.8	....	11.6	11.5	8.9	9.6	10.7	12.7	10.9
No. 4	13.7	11.9	11.8	....	10.1	9.6	10.2	13.3	12.0	12.8	8.2
No. 5	9.7	11.1	13.7	....	11.7	11.5	10.2	12.6	13.5	13.6	10.6
No. 6	11.8	10.8	13.8	....	13.9	11.4	9.6	11.6	12.0	12.3	10.1
No. 7	12.1	8.0	12.9	....	13.5	11.7	11.1	11.5	10.8	8.0	9.6
No. 8	11.2	10.5	12.7	....	13.1	11.4	9.5	11.4	10.2	11.9	10.6
No. 9	12.2	11.2	11.5	....	14.4	11.1	9.7	14.8	10.2	11.3	13.1
No. 10	15.3	11.7	12.2	....	10.4	9.8	9.2	14.6	9.7	9.2	9.5
No. 11	13.2	9.8	12.7	....	15.0	11.5	9.2	11.2	9.3	11.1	8.4
No. 12	12.2	11.6	13.0	....	11.4	12.8	9.9	13.9	10.2	12.3	10.3
No. 13	13.6	10.5	12.3	12.1	12.1	14.2	9.9	9.8	12.6	12.3	10.0
No. 14	13.9	11.1	12.4	9.9	14.0	12.4	8.4	10.1	13.0	11.9	9.1
No. 15	11.5	11.3	9.1	13.9	15.7	11.3	11.0	12.1	9.6	12.4	10.9
No. 16	11.0	10.4	11.7	12.1	11.3	12.6	8.0	14.1	11.7	11.2	9.2
No. 17	11.4	10.2	12.6	12.0	15.4	12.7	9.9	11.4	11.7	12.4	9.5
No. 18	13.8	11.5	13.7	12.8	14.4	12.2	12.7	10.1	10.4	10.4	9.9
No. 19	12.0	9.8	12.2	10.6	9.7	13.2	7.1	11.6	12.4	12.6	9.6
No. 20	11.8	14.3	14.0	9.1	12.8	9.3	8.3	11.5	10.8	10.6	7.6
No. 21	13.7	11.3	13.0	6.2	9.5	10.0	9.3	10.2	10.3	10.3	14.0
No. 22	13.2	12.2	13.0	12.1	11.0	13.1	10.6	12.7	11.9	12.6	9.2
Average	12.55 ±.21	11.06 ±.17	12.66 ±.17	11.08 ±.47	12.60 ±.27	11.72 ±.18	9.74 ±.18	11.88 ±.22	11.15 ±.18	11.56 ±.19	10.11 ±.21
Bushels per acre:											
Average	72.61 ±1.21	63.99 ±.98	73.25 ±.98	64.11 ±2.72	72.90 ±1.56	67.81 ±1.04	56.35 ±1.04	68.73 ±1.27	64.51 ±1.04	66.88 ±1.10	58.49 ±1.21

The yield data obtained are shown in Table 1. The field-row numbers in this table in connection with the designation of the seed planted show the order of planting. No correction was made for stand in the case of rows having 19 plants instead of the full quota of 20. For rows having 18 plants or less, however, the production was calculated to a basis of 20 plants. The yields on the basis of corrected stand have been used in all later computations. Yields of shelled grain calculated to a basis of 12 per cent moisture were computed from ear-corn data by the factors obtained from the shelling and moisture determinations.

The relative yields were calculated according to the formula—

$$\frac{\text{actual yield}}{\left(\frac{c_1+c_2}{C}\right)}=\text{relative yield},$$

in which c_1 and c_2 are the yields of the adjacent row on each side and C is the total average production of the strain (or strains) planted in c_1 and c_2. Thus, in row 2, section 1—

$$\frac{14.4}{\left(\frac{9.8+11.4}{10.3+12.7}\right)}=15.6,$$

in which 10.3 is the average actual yield of No. 201, check, and 12.7 the average actual yield of Whatley, these being the strains grown in rows 1 and 3.

The average plat yields in the summaries (Table 1) are converted to the "bushels per acre" basis by multiplying by 324, the number of such plats in an acre, and dividing by 56, the standard bushel weight of corn.

DISCUSSION OF DATA.

The actual and relative yields agree very well, as is shown graphically in Figure 1. The greatest discrepancy is in the case of No. 201, F_1, which was replicated only 10 times. Even in this case the difference is less than twice the probable error of the actual yield. It seems, therefore, that the number and distribution of replications largely equalized the soil variation. The relative yields are to be preferred, both because they take more definite cognizance of soil variation and because of stand corrections. In rows having deficient stands the adjacent rows are benefited to approximately the same extent as the

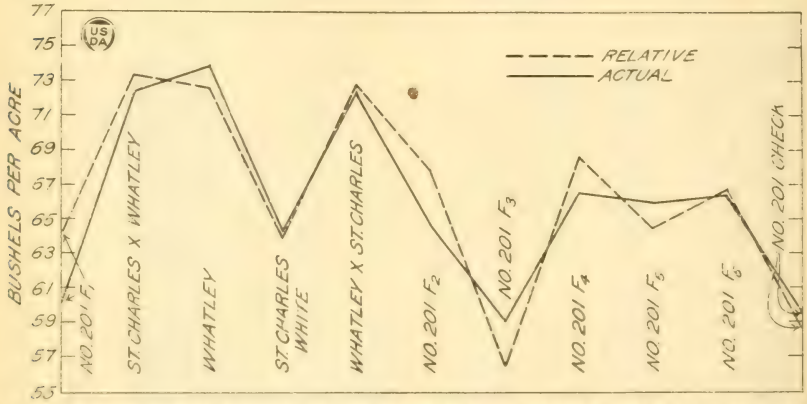

FIG. 1.—Diagram showing the actual and relative yields of Whatley and St. Charles White corn, the crosses between these varieties, and successive generations of No. 201.

rows containing the deficient stand. Comparisons based partly on these adjacent rows, therefore, should tend to reduce any distortion caused by the correction made for stand.

It seems desirable to consider first the relations between the three first-generation crosses. The difference between the yield of Whatley × St. Charles White and that of its reciprocal cross is negligible, and the reciprocal crosses may be considered essentially equal.

No. 201, F_1, is the cross Whatley × St. Charles White, as made in 1914. The object of remaking this cross was to provide seed grown under the same conditions and of the same age as the seed of the later generations. Can Whatley × St. Charles White be substituted for No. 201, F_1, in a comparison of generations? It would seem so. Reference to the results in 1915 (p. 1) shows that seed from the same lot as that used to plant the rows of No. 201, F_1, in the present experiment produced 81.9 bushels per acre, in comparison with a yield of 67 bushels for St. Charles White. This relation agrees sufficiently with that between Whatley × St. Charles White and the St. Charles White in the experiment in 1921 to warrant substituting Whatley × St. Charles White for No. 201, F_1, in comparing the generations.

The productiveness of No. 201, F_1, unquestionably was higher than is shown by the actual-yield data, as indicated both by its relative yield and by a knowledge of the experimental conditions. Nevertheless, it was not as productive as the new seed of the same cross. Its earlier ratio to St. Charles White shows that this loss was due to deterioration and not to any effect of the season during which the seed was grown. This marked reduction in yield, definitely due to age, seems worthy of note.

If the mass selection practiced in the successive generations had any effect on yield, the results fail to show it. The explanation that heterosis is due to the complementary action of dominant growth factors assumes that there are genetic differences between varieties that produce an increased yield when crossed, with the entire F_1 population heterozygous for such factors. Following random mating there would be a reduction in the degree of heterozygosis in the F_2 generation, but no further reduction would occur in later generations.[4] The comparative yields of the different generations are in fair accord with this theory. The F_1 generation of the cross Whatley × St. Charles White was markedly superior to the average of the parents and slightly better than the better parent, Whatley. This superiority was lost in the F_2 generation, which produced somewhat less than the average of the parents. The yield of the F_4, F_5, and F_6 generations, however, was approximately the same as that of No. 201, F_2.

The very low yield of No. 201, F_3, probably was caused by close breeding. As noted, the original F_2 generation was produced in an isolated plat of some 20 plants. The F_3 seed planted in the present experiment was obtained from this F_2 generation, with a high probability of close breeding. It should be noted, however, that the F_3 population would be as heterozygous as a whole as the F_2, barring such factors as may have been eliminated accidentally. It was the individuals that were close bred, and intercrossing among these individuals would immediately restore the heterozygous condition obtaining in the F_2 generation.

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[4] Pearson, Karl. A generalized theory of alternative inheritance, with special reference to Mendel's laws. *In* Phil. Trans. Roy. Soc. London, ser. A, vol. 23, p. 53-86. 1904.

What effect, if any, the selection practiced had on the character of the plants, ears, and kernels is shown in Table 2. The high yield of Whatley evidently was due to the large number of ears, whereas that of the St. Charles White-Whatley crosses was caused by a somewhat smaller number of larger ears. The lower yields of the later generations of No. 201 resulted from a slight reduction in both size and number of ears.

Damage by storms made it impracticable to obtain height data at Burdette, and the number of nodes and height of plants, as given in Table 2, are based on 10 plants at the Arlington Experiment Farm that were selected as representative. The data on height of plants, therefore, is of doubtful significance. The number of nodes is less variable, and these data probably are significant. They indicate that the number of nodes has been reduced slightly by selection.

Data on weight of seed planted were obtained from the hand-pollinated ears grown at Burdette in 1920 and may be taken as representing a fair random sample, as only well-filled ears were used for each lot. There has been a slight increase in average weight of seed resulting from selection.

TABLE 2.—*Data on plants, ears, and kernels of the Whatley and St. Charles White varieties of corn, the crosses between these varieties, and successive generations of No. 201.*

[The results here shown were obtained in 1921 at Burdette, Ark., with the following exceptions: The data in column 8 are from seed from hand-pollinated ears grown in 1920, except No. 201, F_1. The data in columns 9 and 10 are the average for 10 representative plants grown at Arlington Experiment Farm, Va., in 1921.]

Designation.	Number of plants.		Ears per 100 bearing plants.	Average weight of ears.	Ratio of grain to ear corn.	Moisture in shelled grain.	Weight per 100 seeds planted.	Average.	
	Total.	Barren.						Height of plants.	Number of nodes.
1	2	3	4	5	6	7	8	9	10
				Pounds.	*Per cent.*	*Per cent.*	*Grams.*	*Inches.*	
Whatley	94	0	206	0.384	84.6	16.8	35.0	128	21
St. Charles White	92	0	114	.605	85.2	14.8	37.0	123	17
St. Charles White × Whatley	95	3	161	.524	83.6	16.2	38.0	122	19
No. 201, F_1 (1914 seed)	87	7	155	.449	85.0	15.6	29.0	126	19
Whatley × St. Charles White	99	4	157	.476	84.2	16.0	36.5	129	19
No. 201, F_2	99	0	149	.495	85.8	16.3	35.5	125	19
No. 201, F_3	86	0	140	.456	85.7	16.0	37.5	121	18
No. 201, F_4	93	0	145	.460	84.8	16.1	38.5	125	18
No. 201, F_5	96	0	153	.467	85.2	16.5	40.0	122	18
No. 201, F_6	95	0	151	.453	85.0	16.2	39.0	124	18
No. 201, check	86	3	153	.447	85.4	16.0	40.0	119	17

RESULTS OF SELECTION WITHIN SELF-FERTILIZED LINES.

METHOD OF SELECTION.

Selection within self-fertilized lines was begun with No. 201 in 1916 among the F_2 plants. The basis of selection has been the production of sound grain per plant, together with consideration of such factors as maturity, general plant proportions, and freedom from extreme abnormalities. Selection during the first season was based on the production of the individual plants, and 360 self-pollinated ears were obtained. Of these, 61 were selected and planted in ear rows in 1917. Two plantings were made, the first on April 23 and the second on May 11. Desirable ear rows were determined on the basis of performance in the earlier planting, and desirable individual plants in homologous rows of the later planting were self-pollinated. This method of double planting was very satisfactory, as the advance information from the first planting eliminated much unnecessary hand pollination. Its use has been prohibited since 1917 by climatic and soil conditions that prevented the early planting. Preliminary selection consequently has been based on the appearance of the rows at the time of blossoming, final judgment being reserved until autumn. There were 34 ear rows in 1918. Some of the selected ears from the 1918 crop were lost during shipment, and only 20 ear rows were planted in 1919. The numbers of ear rows mentioned refer only to those representing continuously selfed lines from the original 1916 selection. Other selections that have been introduced from time to time need not be considered here.

TABLE 3.—*Pedigrees of ears representing self-fertilized strains of No. 201 corn planted at King, La., in 1920 to obtain crosses for comparison at Burdette, Ark., in 1921, showing the relation of such ears to the original cross.*

[EXPLANATION.—In 1914 the Whatley variety was crossed by St. Charles White. In 1915 the F_1 cross was grown, open fertilized. In 1916 the F_2 cross was grown, and 360 ears were self-fertilized. The subsequent use of pedigree numbers and strain designations is shown in the table.]

Pedigree numbers, No. 201.				1920. Strain designations.
1917	1918	1919	1920	
2	2-2	2-2-1 2-2-2 2-2-3	2-2-1-, 1, 2, 3 2-2-2-, 3, 4 2-2-3-, 3, 4, 5	2-2-
3	3-1	3-1-1	3-1-1-, 2, 3, 4	3-1-
5	5-1	5-1-1 5-1-2 5-1-3	5-1-1-, 1, 3, 4 5-1-2-, 1, 2, 3 5-1-3-, 1, 2	5-1-
7	7-1	7-1-1	7-1-1-, 1, 2, 3	7-1-
	7-4	7-4-1 7-4-2	7-4-1-, 5, 7 7-4-2-, 1, 2, 3, 4, 5, 6	7-4-
9	9-2	9-2-1 9-2-2 9-2-3	9-2-1-, 1, 2, 3 9-2-2-, 1, 2, 3, 4 9-2-3-, 1, 2, 3	9-2-
10	10-3	10-3-1 10-3-2	10-3-1-1 10-3-2-1	10-3-
12	12-1	12-1-1 12-1-2	12-1-1-, 2, 3 12-1-2-, 1, 2	12-1-
13	13-1	13-1-3	13-1-3-1	13-1-
15	15-1	15-1-1 15-1-2	15-1-1-, 1, 2 15-1-2-, 1, 2, 3, 4	15-1-

METHOD OF CROSSING.

From the 1919 ear-row plat 53 selfed ears were obtained for use in crossing and for further breeding operations. The pedigrees of these ears and their relation to the original cross, Whatley × St. Charles White, are shown in Table 3. Seed was composited to represent each of the 10 strains shown under "Strain designations" in the table, and a row of each was planted at King, La., in 1920. Crosses were made between the strains by hand pollinating, pollen for the crosses being taken from three or more plants in the desired row in order more thoroughly to represent the strain as a whole. Some additional crosses were made at Burdette, Ark., where the same 53 ears were planted in the 1920 breeding plat. There is no reason for differentiating between the seed grown in Louisiana and in Arkansas. Several ears representing each cross were obtained, some of which were discarded because of damage of different kinds. The number finally used varied from one to five, as shown in Table 4 under the heading "Number of seed ears."

METHOD OF COMPARISON.

The one to five ears representing each particular cross were shelled and mixed together. The productiveness of 41 of these crosses was compared at Burdette, Ark., in 1921 in a plat adjacent to the mass-selection experiment. Three rows, consisting of a 20-plant row of a cross between two 20-plant check plats, constituted a unit. Each cross was grown in three or four of these units. The 36 crosses replicated three times had these units, end to end, in sections 1, 2, and 3, or 4, 5, and 6. The five crosses replicated four times had the units adjacent in section 6. The check plats were planted with seed of No. 201, check. The order of planting is shown in Table 4. The environmental conditions were the same as those described in connection with the mass-selection experiment.

TABLE 4.—*Yields of crosses between inbred strains of No. 201 corn at Burdette, Ark., in 1921.*

[EXPLANATION.—(1) The number of seed ears noted in column 3 were shelled together to plant the rows indicated. (2) The stand corrections for columns 6, 10, and 14 are made only for those rows for which data are given. (3) Data in columns 6, 7, 10, 11, 14, and 15 for rows having 18 plants or less are calculated to full-stand basis. (4) The relative yields (columns 7, 11, 15, and 16) are computed by taking twice the actual yields divided by the yields of the two adjacent rows.]

Field row.	Sections 1, 2, and 3.		Section 1.				Section 2.				Section 3.				Average of 3 replications, relative yield.
	Seed planted.	Number of seed ears.	Number of plants.	Yield of ears per row.			Number of plants.	Yield of ears per row.			Number of plants.	Yield of ears per row.			
				Field weight.	Corrected-stand basis.			Field weight.	Corrected-stand basis.			Field weight.	Corrected-stand basis.		
					Actual.	Relative.			Actual.	Relative.			Actual.	Relative.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	No. 201-.			*Lbs.*	*Lbs.*	*P. c.*		*Lbs.*	*Lbs.*	*P. c.*		*Lbs.*	*Lbs.*	*P. c.*	*P. c.*
No. 49	Check	....	20	16.4	.....	.....	19	14.4	.....	.....	20	14.3	.....	.....	....
No. 50	9-2-×5-1-	2	19	15.8	.....	93.2	20	14.7	.....	108.5	19	14.3	.....	101.8	101.17
No. 51	Check	....	16	14.0	17.5	.....	20	12.7	.....	.....	20	13.8	.....	.....	....
No. 52	10-3-×15-1-	3	20	18.0	.....	118.8	20	18.4	.....	136.8	19	16.2	.....	109.8	121.80
No. 53	Check	....	20	12.8	.....	.....	20	14.2	.....	.....	20	15.7	.....	.....	....
No. 54	12-1-×3-1-	2	19	9.4	.....	76.7	20	14.4	.....	109.9	20	14.9	.....	94.9	93.83
No. 55	Check	....	19	11.7	.....	.....	19	12.0	.....	.....	20	15.7	.....	.....	....
No. 56	13-1-×15-1-	3	20	11.8	.....	95.5	20	11.7	.....	91.4	20	14.4	.....	97.0	94.63
No. 57	Check	....	19	13.0	.....	.....	20	13.6	.....	.....	20	14.0	.....	.....	....
No. 58	15-1-×3-1-	1	19	11.0	.....	82.7	19	13.3	.....	96.4	20	17.4	.....	122.5	100.53
No. 59	Check	....	20	13.6	.....	.....	20	14.0	.....	.....	20	14.4	.....	.....	....
No. 60	2-2-×12-1-	2	20	13.4	.....	108.1	20	12.9	.....	96.3	19	16.2	.....	106.6	103.67
No. 61	Check	....	18	10.9	11.2	.....	20	12.8	.....	.....	20	16.0	.....	.....	....
No. 62	3-1-×7-1-	2	20	11.9	.....	100.8	19	10.5	.....	93.8	20	11.3	.....	79.3	91.30
No. 63	Check	....	18	11.2	12.4	.....	20	9.6	.....	.....	20	12.5	.....	.....	....
No. 64	7-1-×3-1-	1	17	12.1	14.2	107.6	20	9.3	.....	102.8	20	11.4	.....	80.6	97.00
No. 65	Check	....	20	14.0	.....	.....	20	8.5	.....	.....	18	14.2	15.8	.....	....
No. 66	7-4-×15-1-	2	20	12.0	.....	87.0	20	6.4	.....	73.1	20	13.8	.....	87.9	82.67
No. 67	Check	....	20	13.6	.....	.....	19	9.0	.....	.....	20	15.6	.....	.....	....

TABLE 4.—*Yields of crosses between inbred strains of No. 201 corn at Burdette, Ark., in 1921*—Continued.

	Sections 1, 2, and 3.		Section 1.				Section 2.				Section 3.				Average of 3 replications, relative yield.
				Yield of ears per row.				Yield of ears per row.				Yield of ears per row.			
					Corrected-stand basis.				Corrected-stand basis.				Corrected-stand basis.		
Field row.	Seed planted.	Number of seed ears.	Number of plants.	Field weight.	Actual.	Relative.	Number of plants.	Field weight.	Actual.	Relative.	Number of plants.	Field weight.	Actual.	Relative.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	No. 201-.			*Lbs.*	*Lbs.*	*P. c.*		*Lbs.*	*Lbs.*	*P. c.*		*Lbs.*	*Lbs.*	*P. c.*	*P. c.*
No. 68	9-2-×12-1-	3	18	10.6	12.9	100.7	20	10.8	.....	100.9	20	13.0	.....	82.0	94.53
No. 69	Check	....	19	12.0	.....	.....	20	12.4	.....	.....	20	16.1	.....	.....	....
No. 70	10-3-×2-2-	3	20	17.2	.....	127.9	20	12.9	.....	102.4	19	14.8	.....	94.6	108.30
No. 71	Check	....	20	14.9	.....	.....	20	12.8	.....	.....	20	15.2	.....	.....	....
No. 72	12-1-×7-1-	2	20	12.3	.....	85.1	20	11.8	.....	95.9	19	15.0	.....	97.4	92.80
No. 73	Check	....	20	14.0	.....	.....	20	11.8	.....	.....	20	15.6	.....	.....	....
No. 74	13-1-×10-3-	3	20	19.7	.....	141.2	19	11.8	.....	105.8	20	17.4	.....	121.7	122.90
No. 75	Check	....	20	13.9	.....	.....	20	10.5	.....	.....	20	13.0	.....	.....	....
No. 76	15-1-×12-1-	2	20	15.0	.....	103.8	20	11.5	.....	116.8	19	13.3	.....	102.3	107.63
No. 77	Check	....	20	15.0	.....	.....	20	9.2	.....	.....	20	13.0	.....	.....	....
No. 78	2-2-×13-1-	2	20	12.0	.....	80.0	20	8.5	.....	95.0	20	9.6	.....	76.2	83.73
No. 79	Check	....	20	15.0	.....	.....	20	8.7	.....	.....	20	12.2	.....	.....	....
No. 80	3-1-×9-2-	1	20	14.0	.....	86.4	19	9.8	.....	100.0	20	11.2	.....	93.3	93.23
No. 81	Check	....	20	17.4	.....	.....	19	10.9	.....	.....	20	11.8	.....	.....	....
No. 82	7-1-×5-1-	2	20	13.0	.....	84.1	19	10.7	.....	88.4	18	10.2	11.3	97.8	90.10
No. 83	Check	....	20	13.5	.....	.....	20	13.3	.....	.....	20	11.3	.....	.....	....

	Sections 4, 5, and 6.		Section 4.				Section 5.				Section 6.				Average of 3 replications.
No. 49	Check	....	20	15.6	.....	.....	18	12.0	13.3	.....	17	11.3	13.3	.....	....
No. 50	15-1-×13-1-	4	19	12.8	.....	83.7	19	9.4	.....	82.8	19	10.5	.....	81.7	82.73
No. 51	Check	....	20	15.0	.....	.....	19	9.4	.....	.....	18	11.7	12.4	.....	....
No. 52	7-1-×7-4-	2	20	11.8	.....	85.2	20	7.0	.....	76.9	15	7.4	9.9	82.5	81.53
No. 53	Check	....	20	12.7	.....	.....	16	7.0	8.8	.....	17	9.9	11.6	.....	....
No. 54	7-4-×9-2-	3	20	12.3	.....	95.3	20	8.7	.....	104.8	20	9.8	.....	94.2	98.10
No. 55	Check	....	19	13.1	.....	.....	20	7.8	.....	.....	19	9.2	.....	.....	....
No. 56	10-3-×13-1-	4	20	15.6	.....	112.2	20	8.9	.....	116.3	20	14.2	.....	145.6	124.70
No. 57	Check	....	18	13.2	14.7	.....	19	7.5	.....	.....	19	10.3	.....	.....	....
No. 58	13-1-×7-4-	2	15	9.6	12.8	81.8	20	7.6	.....	94.4	20	10.7	.....	109.7	95.30
No. 59	Check	....	20	16.6	.....	.....	19	8.6	.....	.....	20	9.2	.....	.....	....
No. 60	7-1-×9-2-	1	16	6.6	8.3	68.6	20	9.9	.....	83.9	20	8.8	.....	86.3	79.60
No. 61	Check	....	18	6.8	7.6	.....	20	15.0	.....	.....	19	11.2	.....	.....	....
No. 62	7-4-×5-1-	1	18	12.2	13.6	128.3	20	16.3	.....	120.7	20	10.0	.....	88.1	112.37
No. 63	Check	....	20	13.6	.....	.....	19	12.0	.....	.....	19	11.5	.....	.....	....
No. 64	13-1-×12-1-	4	20	10.0	.....	70.4	19	14.0	.....	104.9	20	11.2	.....	92.9	89.40
No. 65	Check	....	19	14.8	.....	.....	20	14.7	.....	.....	20	12.6	.....	.....	....
No. 66	5-1-×3-1-	2	20	15.8	.....	105.3	19	15.1	.....	111.4	20	12.5	.....	96.9	104.53
No. 67	Check	....	20	15.2	.....	.....	19	12.4	.....	.....	19	13.2	.....	.....	....
No. 68	10-3-×7-4-	3	20	18.2	.....	119.0	20	16.4	.....	123.3	20	16.9	.....	120.3	120.87
No. 69	Check	....	20	15.4	.....	.....	20	14.2	.....	.....	19	14.9	.....	.....	....
No. 70	15-1-×7-1-	1	20	13.2	.....	86.0	20	11.6	.....	85.9	17	11.2	13.2	85.4	85.77
No. 71	Check	....	20	15.3	.....	.....	20	12.8	.....	.....	20	16.0	.....	.....	....
No. 72	7-1-×12-1-	4	20	12.5	.....	85.9	19	11.1	.....	84.7	20	13.4	.....	86.5	85.70
No. 73	Check	....	19	13.8	.....	.....	20	13.4	.....	.....	20	15.0	.....	.....	....
No. 74	2-2-×15-1-	2	17	11.3	13.3	97.1	20	12.5	.....	91.2	19	14.8	.....	92.8	93.70
No. 75	Check	....	20	13.6	.....	.....	20	14.0	.....	.....	18	15.2	16.9	.....	....
No. 76	3-1-×15-1-	1	18	12.3	14.8	110.4	20	15.0	.....	108.7	19	14.5	.....	94.2	104.43
No. 77	Check	....	19	13.2	.....	.....	20	13.6	.....	.....	16	11.1	13.9	.....	....
No. 78	13-1-×9-2-	3	16	10.2	12.8	90.5	19	15.4	.....	107.7	18	11.8	13.1	93.2	97.13
No. 79	Check	....	18	13.6	15.1	.....	20	15.0	.....	.....	20	14.2	.....	.....	....
No. 80	7-1-×13-1-	5	15	9.2	12.3	77.6	18	13.0	14.4	96.6	19	11.4	.....	84.8	86.33
No. 81	Check	....	20	16.6	.....	.....	19	14.8	.....	.....	20	12.7	.....	.....	....
No. 82	10-3-×12-1-	2	20	15.4	.....	105.8	18	13.4	14.9	108.4	15	9.7	12.9	89.0	101.07
No. 83	Check	....	19	12.5	.....	.....	19	12.7	.....	.....	15	12.2	16.3	.....	....
No. 84	15-1-×7-4-	2	18	12.0	13.3	111.8	18	12.4	13.8	101.1	17	11.2	13.2	94.0	102.30
No. 85	Check	....	16	9.0	11.3	.....	19	14.6	.....	.....	18	10.6	11.8	.....	....
No. 86	7-4-×13-1-	4	19	12.4	.....	99.2	20	12.6	.....	90.3	20	13.2	.....	105.6	98.37
No. 87	Check	....	19	13.7	.....	.....	19	13.3	.....	.....	20	13.2	.....	.....	....

TABLE 4.—*Yields of crosses between inbred strains of No. 201 corn at Burdette, Ark., in 1921*—Continued.

Section 6.							
				Yield of ears per row.			
					Corrected-stand basis.		
Field row.	Seed planted.	Number of seed ears.	Number of plants.	Field weight.	Actual.	Relative.	Average of 4 replications, relative yield.
1	2	3	4	5	6	7	16
	No. 201-.			*Lbs.*	*Lbs.*	*P. c.*	*P. c.*
No. 8.	Check		20	7.0			
No. 9.	2-2-×10-3-.	3	20	6.5		87.8	
No. 10.	Check		20	7.8			
No. 11.	2-2-×10-3-.		20	7.8		111.4	
No. 12.	Check		20	6.2			
No. 13.	2-2-×10-3-.		20	9.0		105.9	
No. 14.	Check		20	10.8			
No. 15.	2-2-×10-3-.		20	10.7		91.1	99.05
No. 16.	Check		20	12.7			
No. 17.	3-1-×2-2-.	2	19	12.2		94.9	
No. 18.	Check		20	13.0			
No. 19.	3-1-×2-2-.		20	12.0		92.3	
No. 20.	Check		20	13.0			
No. 21.	3-1-×2-2-.		20	9.7		81.5	
No. 22.	Check		18	9.7	10.8		
No. 23.	3-1-×2-2-.		18	8.2	9.1	92.4	90.28
No. 24.	Check		18	8.0	8.9		
No. 25.	5-1-×2-2-.	2	20	10.9		120.4	
No. 26.	Check		19	9.2			
No. 27.	5-1-×2-2-.		20	12.0		118.8	
No. 28.	Check		20	11.0			
	No. 201-.			*Lbs.*	*Lbs.*	*P. c.*	*P. c.*
No. 29.	5-1-×2-2-.		20	13.3		111.8	
No. 30.	Check		19	12.8			
No. 31.	5-1-×2-2-.		20	14.5		102.1	113.28
No. 32.	Check		17	13.3	15.6		
No. 33.	7-1-×15-1-.	2	17	11.7	13.8	99.3	
No. 34.	Check		20	12.2			
No. 35.	7-1-×15-1-.		20	8.1		80.6	
No. 36.	Check		20	7.9			
No. 37.	7-1-×15-1-.		19	4.9		59.4	
No. 38.	Check		20	8.6			
No. 39.	7-1-×15-1-.		14	5.7	8.1	100.0	84.83
No. 40.	Check		20	7.6			
No. 41.	7-4-×2-2-.	3	19	6.9		77.5	
No. 42.	Check		18	9.2	10.2		
No. 43.	7-4-×2-2-.		19	14.8		123.3	
No. 44.	Check		20	13.8			
No. 45.	7-4-×2-2-.		18	12.2	13.6	107.1	
No. 46.	Check		17	9.9	11.6		
No. 47.	7-4-×2-2-.		15	9.0	12.0	113.2	105.28
No. 48.	Check		14	6.7	9.6		

SUMMARY OF RELATIVE YIELDS PER ACRE.

[Data in bushels.]

Staminate parent strains, No. 201-.	Pistillate parent strains, No. 201-.									
	2-2-.	3-1-.	5-1-.	7-1-.	7-4-.	9-2-.	10-3-.	12-1-.	13-1-.	15-1-.
2-2-		54.40	68.26		63.44		65.26			
3-1-			62.99	58.45				56.54		60.58
5-1-				54.29	67.71	60.97				
7-1-		55.02						55.92		51.69
7-4-				49.13			72.84		57.43	61.65
9-2-		56.18		47.97	59.12				58.53	
10-3-	59.69								74.06	
12-1-	62.47			51.64		56.96	60.90		53.87	64.86
13-1-	50.46			52.02	59.28		75.14			49.85
15-1-	56.46	62.93		51.12	49.82		73.40		57.02	
Average value:										
As ♀	57.27	57.13	65.63	52.09	59.87	58.97	69.51	56.23	60.18	57.73
As ♂	62.84	59.64	60.99	54.21	60.26	55.45	66.88	58.45	57.35	58.46
As ♀ and ♂	60.06	58.39	62.84	52.73	60.05	56.62	68.76	57.90	58.77	58.13

EXPERIMENTAL DATA.

The experimental data are presented in Table 4. The yields are given in pounds of ear corn, no moisture or shelling calculations having been made. However, all of the corn was dry enough to shell. The field weights of those rows having 18 plants or less were corrected for stand. These corrected yields were calculated to relative percentage yields in terms of the average of the two adjacent check plats. The averages of the three or four relative yields of each cross are used as the basis of comparisons between the crosses. The data as summarized in Table 4 are relative yields in bushels per acre. These were calculated by multiplying the average relative percentage yields by 60.26, which is the average yield per acre of the 135 check plats. The data in this summary (Table 4) are arranged to show the productiveness of the crosses as influenced by the parent strains involved. The relative values of the strains as pistillate parents, as staminate parents, and as both pistillate and staminate parents also are given.

DISCUSSION OF DATA.

The only definite promise of increased yields of corn from breeding methods involving selection within self-fertilized lines is the utilization of F_1 crosses or double crosses between such lines. Other possibilities suggest themselves and should be investigated, but immediate efforts to obtain practical results must be based upon the utilization of crosses. Obviously, from this point of view the true value of a pure line lies in the productiveness of its crosses rather than in its own inherent vigor and yield. With this in mind, the crosses here considered were compared in order to measure the value of the parent strains, and the relative productiveness of the crosses inter se is the point of chief importance. The relative yields of the crosses and of comparable noninbred strains also are of some interest. The lines had been self-fertilized only four generations prior to crossing, however, and selection on the basis of vigor and yield had tended to retain the more heterozygous lines. The results consequently are not offered as any measure of the ultimate possibilities of this method of breeding.

The average yield of the 135 check plats was 60.26 bushels per acre in the comparison of crosses. The same strain, No. 201, check, yielded 58.49 ± 1.21 bushels per acre, relative yield, in the comparison of generations. The relative yields of the crosses, therefore, may be compared directly with the relative yields of the noninbred generations. The yield of Whatley × St. Charles White was 72.90, and the average of No. 201, F_4, F_5, and F_6 was 66.71 bushels per acre. There were four crosses that approximated the production of Whatley × St. Charles White and four more that approximated the average yield of the three later generations of No. 201. On the other hand, 33 of the crosses yielded from 4.6 to 20.1 bushels less than the later noninbred generations of No. 201.

These relations are shown graphically in Figure 2. The horizontal broken lines in this figure represent, respectively, the yield of Whatley × St. Charles White and the average production of No. 201, F_4, F_5, and F_6. The yields of the individual crosses between the selfed strains are shown by the location of the short horizontal lines projecting from the heavy vertical bars. A bar connects the yields of all crosses in which one strain was involved as a parent; consequently each cross is represented twice, once in connection with each parent. The mean yields of the groups of crosses are shown by the points on the bars that are connected by the solid line.

Because of the fact that all the parent strains are not represented equally in the crosses, the mean yields are inconclusive. However, both the upper and lower extremities of the bars in Figure 2 follow the line connecting the mean-yield points in a general way. There is an evident tendency, therefore, for the crosses having one parent in common to react similarly. At the same time there are marked deviations from this tendency. The most striking exception is in the case of the crosses involving the 13–1– strain. The reciprocal crosses between the 10–3– and 13–1– strains yielded 74.06 and 75.14 bushels per acre, or 15 bushels more than the next best cross in which strain 13–1– was used. The average of the 13–1– crosses is unduly high because of this, and in fact would be about 55 bushels if its crosses with 10–3– were not considered. This would be less than the crosses of any of the other strains except 7–1–. Undue influence in the opposite direction is evident in the crosses involving the 9–2– family. Here a single extremely poor cross with 7–1–, yielding 8 bushels less than the next better cross, has lowered the mean yield nearly 2 bushels per acre.

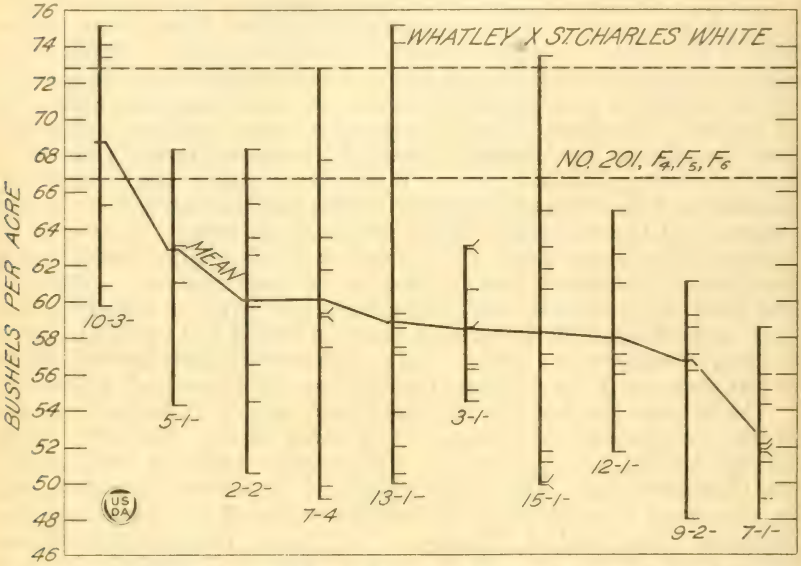

FIG. 2.—Diagram showing the relative yields of Whatley × St. Charles White corn, of later generations of No. 201, and of 41 crosses between self-fertilized lines of No. 201 grouped to show the productiveness by families.

On the whole, however, the tendency for certain strains to produce satisfactory crosses is promising. Certainly the results seem to offer a more logical basis for future selection and experiment than is provided by the relative vigor of the selfed lines. This is demonstrated particularly well in the case of the 10–3– strain. Indeed, the most striking result in the experiment is the high yield of crosses having 10–3– as a parent. The mean yield of these seven crosses exceeds the productiveness of any single one of the 34 crosses not involving 10–3–. In spite of this, the 10–3– selfed lines are so thoroughly unpromising that they were marked for elimination during the season of 1921 before the results of the crossing experiments were at hand. This emphasizes the importance of selection based in part at least on the performance of the crosses.

CONCLUSIONS.

The F_1 generation of the cross Whatley × St. Charles White was markedly more productive than the average of its parents, yielding slightly more than its better parent, Whatley. Open-fertilized mass selection was ineffective in maintaining this high productiveness, the yields of the later generations approximating the average of the parents. This is what would be expected following random mating if heterosis is due to the complementary action of dominant growth factors. It was necessary to select the earlier segregates, as well as those having larger ears, because of practical considerations. Selection, therefore, was away from the type of Whatley, the parent which was higher in yield, but which was undesirable because of its lateness and small ears. On the other hand, the F_1 generation produced as much as Whatley and matured slightly, if at all, later than St. Charles White. The value of the F_1 generation, therefore, was in its increased efficiency in production rather than in an actual increased yield, Whatley being taken as the criterion.

Although it was impossible to retain the efficiency of the F_1 generation of the cross, the method of crossing followed by mass selection has established a variety of economic value for the locality. No. 201 has a good length of season, well-proportioned plants, and ears of good quality. It has been grown on a commercial scale for several years with good results, several hundred acres having been grown in 1921. In the present experiments as well as in others it has yielded somewhat more than St. Charles White and shown itself to be among the higher yielding varieties for this section. It is not, however, the outstanding corn that it was in the F_1 generation.

Strains have been isolated by selection within self-fertilized lines which when intercrossed have produced as much as the original F_1 varietal cross in a single season's comparison. Whether these crosses can repeat or not and whether better ones can be found remains to be determined. So far there has been no advantage in yield from the laborious methods of hand pollinating over what could have been obtained by growing the F_1 varietal cross each year. Selection has been carried on for only four years and on a somewhat limited scale, however, and it seems reasonable to hope for higher yielding crosses when further combinations have been tested.

Of necessity, selection so far has been rather a haphazard affair, based on assumptions that may or may not be founded on fact. The results are promising, therefore, in the tendency shown by certain strains to give high-yielding crosses. The behavior of strain 10-3- when selfed and when crossed is of particular interest in this connection. Two possibilities already have suggested themselves in explanation of the value of this strain in combination, and it is hoped that investigation will determine what the controlling conditions are.

With the solution of this and similar problems as they present themselves from time to time, it should be possible to formulate principles of selection based upon fact. Until that time, however, reliance must be placed upon empirical methods, and the best chances for success seem to lie in the use of large numbers and in avoiding preconceived notions as to what are the best pure lines.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE.

January 11, 1924.

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